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THE EFFECT OF STOCKING DENSITY AND SIZE SORTING ON THE YIELD OF *Macrobrachium rosenbergii*

Report No 88-169-K

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ABSTRACT

The effects of stocking density and size sorting on the yield of *Macrobrachium rosenbergii* were studied. Survival, mean size and change in biomass were found to be inversely related to initial stocking density. Variance in the size of prawns was only a function of final weight. An optimization index was developed using parameters affected by stocking density. Two response surface models were developed using the index to assist the definition of optimum stocking densities for prawns of post larval size to those with mean weights up to 14.0 g. Limited control of prawn population dynamics appears feasible through the manipulation of stocking density combined with size sorting.

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EXECUTIVE SUMMARY

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P. Niklas and J.K. Kwik
Biological Research Section
Chemical Research Department

Since market value is a direct function of weight, high production of prawns of uniformly large size would increase the profitability of any prawn aquaculture scheme. Survival, mean weight, variance in individual size and population structure have been found to be related to stocking density. The present study examined the effects of stocking density and size sorting on these paramenters.

The study consisted of four eight week experiments. Prawns from 0.2 to 27.4 g were stocked at densities from 5 to 225 animals/m^2. Prawns from previous experiments were reused in subsequent experiments to simulate an 8 week sorting cycle in a 32 week growout period. Results showed that survival, mean size and change in biomass were inversely related to stocking density. Size variance was merely a function of final weight. An optimization index based on the parameters affecting stocking density was formulated. A model, defining the optimum densities for maximum production of prawns grown in the intensive culture system presently used, was derived from the optimization index.

Results indicated post-larval and juvenile prawns can be raised successfully using the culture system developed to date. However, further research is required to develop intensive culturing techniques for sexually mature prawns.

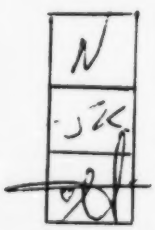

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TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	METHODS	2
2.1	Experimental	2
2.2	Data Analysis	2
3.0	RESULTS	4
3.1	Survival	4
3.2	Size	6
3.3	Biomass	10
3.4	Optimization Index	14
4.0	DISCUSSION	17
4.1	Survival	17
4.2	Size	18
4.3	Biomass	18
4.4	Optimization Index	19
5.0	CONCLUSIONS	20
ACKNOWLEDGEMENTS		21
REFERENCES		22
APPENDICES		24
DISTRIBUTION		last page

LIST OF TABLES

	Page
TABLE 1 - Experimental Design - Summary of Stocking Densities and Size Ranges	3
TABLE 2 - Models of the Change in Mean Weights of Prawns	9
TABLE 3 - Models of the Change in Biomass of Prawns	9

LIST OF FIGURES

FIGURE 1 - Survival vs Stocking Density of Juvenile Prawns	5
FIGURE 2 - Contours of Survival (%) of Juvenile Prawns	7
FIGURE 3 - Contours of Survival (%) of Prawns of all Size Classes	8
FIGURE 4 - Standard Deviations of Final vs Initial Transformed Weights of Prawns of all Size Classes	11
FIGURE 5 - Change in Biomass of Prawns of All Size Classes	12
FIGURE 6 - Change in Biomass vs Density of Juvenile Prawns	13
FIGURE 7 - Juvenile Prawns Optimization Index Contours	15
FIGURE 8 - Prawns of All Size Classes Optimization Index Contours	16

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To: Dr. D. Mills
Director of Research

THE EFFECT OF STOCKING DENSITY AND SIZE SORTING ON THE YIELD OF *Macrobrachium rosenbergii*

1.0 INTRODUCTION

Survival, mean weight, variance in individual size and skewness of the population size distribution have been found to be inversely related to stocking density of *Macrobrachium rosenbergii* (Ra'anan and Cohen, 1984). Experience has shown high survival can be maintained at high densities only while the animals are small. To maintain high survival as the animals grow, lower stocking densities are required. Stocking density is limited by water quality and the socio-physical interaction of animals. The latter results in heterogenous individual growth which contributes to the size variance and positively skewed nature of prawn populations (Ra'anan and Cohen, 1984). Variance and skewness increase as mean weight increases. Control of these parameters may be feasible by manipulating stocking density. Production of large prawns of uniform size would result in significant marketing advantages as market value is a direct function of weight.

As prawn densities are adjusted, the animals can be size sorted. Pooling animals of similar size artificially controls population variance and skewness, reduces aggression (Segal and Roe, 1975) and increases survival (Malecha, 1986). There is evidence that culling the large males responsible for the skewness in the population allows compensatory growth in the remaining smaller males (Ra'anan and Sagi, 1985). Size sorting also allows efficient harvesting of marketable prawns on a timely basis.

The objective of this study is to derive a model to predict the optimum stocking densities for prawns grown under intensive culture conditions. Optimum stocking density is the density at which a combination of density, survival, increase in biomass and

mean size are optimized and size variation and skewness of the prawn population are minimized.

2.0 METHODS

2.1 Experimental

Post-larval Macrobrachium rosenbergii were obtained from Blue Lobster Farms, Madera, California. The prawns were eight weeks post larvae at the time of initial stocking. Animals were stocked in 2x1x1.2 m (LxWxH) cages made of 16/14 PVC-coated fiberglass screen and provided with one horizontal and one horizontal/vertical substrate as described in OHRDR 87-31-K. Cages were placed in 6x7x0.8 m (LxWxH) concrete pools with recirculated water heating systems and aerators (OHRDR C85-12-K). Pools were supplied with Etobicoke tap water at a rate resulting in a ten day turnover. Daily temperatures averaged approximately $29 \pm 1^{o}C$ in each of the pools. Rangen shrimp grower was provided ad libitum twice daily Monday through Friday.

The experimental design consisted of four eight week experiments. Prawns from previous experiments were reused in subsequent experiments to simulate an eight week sorting cycle in a 32 week growout period. Table I summarizes the various stocking densities and size ranges used for the experiments. The density ranges were chosen so that the highest and lowest density for each size class would bracket optimum densities estimated from prawn survival in previous experiments (OHRDRs 87-31-K, C85-12-K). The number of experimental conditions in each experiment depended on the stock available and the desired experimental design. Prawns were weighed in lots of 25 at the beginning of the first experiment and were weighed individually at the beginning and end of experiments thereafter. At the beginning of subsequent experiments animals from the previous experiment were pooled, size sorted and restocked at new densities. During the first eight week period all cages were in the same pool. During subsequent eight week periods, replicates (2) for each stocking density were placed in two separate pools.

2.2 Data Analysis

The data were subjected to response surface analysis which allows determination of optima for interactions by two or more independent variables. Prawn size and stocking density were considered as two independent variables affecting survival and population dynamics. The Box2 computer program used was described in Ontario Hydro Research Division Report 75-484-K and was adapted for use on a MicroVAX II. The program fits a second order polynomial in transformed variables to the results taking the form

TABLE 1

EFFECT OF STOCKING DENSITY AND SIZE SORTING ON THE YIELD OF *M. rosenbergii*

EXPERIMENTAL DESIGN
SUMMARY OF STOCKING DENSITIES AND SIZE RANGES

EXPERIMENT	DENSITY/m^2	SIZE RANGE (g)	REPLICATES
1	75	0.2-1.0	3
	150	0.2-1.0	3
	225	0.2-1.0	3
2	37	0.8-3.4	2
	75	0.8-3.5	2
	112	0.8-3.5	2
	24.5	3.5-6.5	2
	50	3.5-6.5	2
	75	3.5-6.5	2
3	25	5.0-8.6	2
	45	5.0-8.6	2
	67	5.0-8.6	2
	22.5	8.7-12.9	2
	32.5	8.7-12.7	2
	43.5	8.7-12.9	2
	20	12.9-17.5	1
	24	13.0-16.7	1
4	5	12.1-17.8	2
	17.5	12.3-17.5	2
	25	12.4-17.5	2
	5	17.6-27.4	2
	9.5	17.3-25.4	2
	15	17.4-25.9	2

$$y^{\gamma} = b_o x_o + b_1 x_1^{\alpha 1} + b_2 x_2^{\alpha 2} + b_{11} x_1^{2\alpha 1} + b_{22} x_2^{2\alpha 2} + b_{12} x_1^{\alpha 1} x_2^{\alpha 2}$$

where y^{γ} = calculated response (survival, optimization index)
$b_o x_o$ = intercept value (where $x_1 = x_2 = 0$)
x_1 = first independent variable (initial size)
x_2 = second independent variable (stocking density)
α_1, α_2 = power transformations of independent variables

and where α_1, α_2 and γ are power transformations of the independent (x_1 and x_2) and dependent (y) variables respectively. Both transformed and untransformed (where $\alpha_1 = \alpha_2 = \gamma = 1$) models are fitted by the program. The transformations are determined via an iterative computer procedure which minimizes residual variance.

Since the number of replicates used throughout the experiment were not constant, results from each replicate were input individually for the response surface analysis. This resulted in the loss of the "lack of fit" term in the analysis of variance, but retained the inherent variability of the data.

3.0 RESULTS

Summaries of the four eight week experiments appear in Appendix 1. Survival is expressed as a percentage of the number stocked. Change in mean weight is calculated as the ratio of the difference between final and initial mean weight to the initial mean weight. Change in biomass and standard deviation are calculated as the ratio of the final to initial values.

3.1 Survival

The experimental design for Weeks 0-8, 8-16 and 16-24 appeared to bracket optimum stocking densities, however, the poor survival for Weeks 24-32 suggested experimental stocking densities were above optima for the size classes used. Numerous berried females were observed at the end of 24 weeks showing the onset of sexual maturity which occurs at about six months (Malecha, 1980). Prawns display greater territorial behavior when sexually mature. Therefore the results were divided into two categories; juvenile, (< 12 grams) and all size classes.

Survival rate tended to decrease with increases in stocking density. This trend was apparent in all experiments except the 8 to 16 week experiment and for the small prawns in the final experiment (Figure 1).

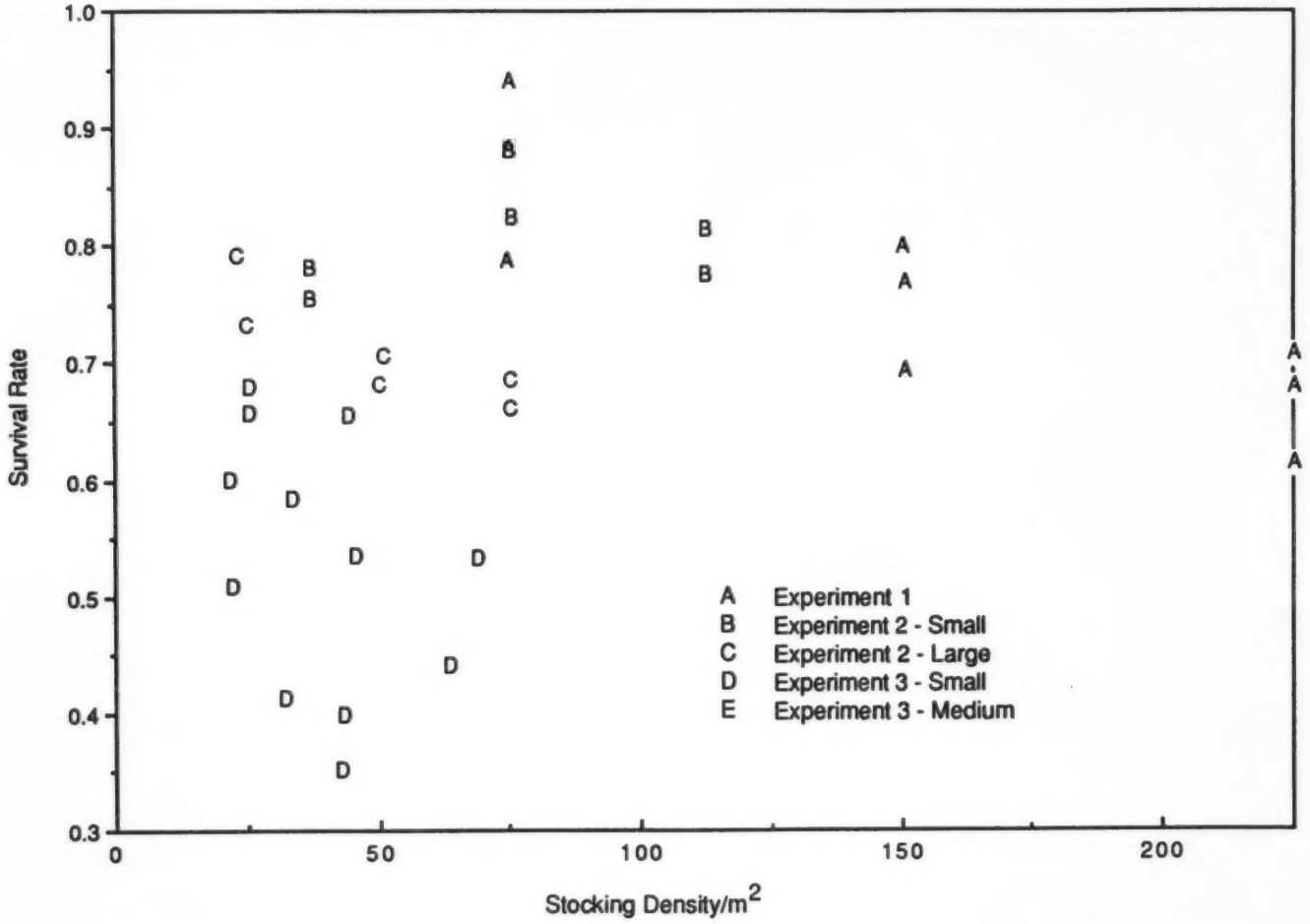

FIGURE 1

SURVIVAL VS STOCKING DENSITY OF JUVENILE PRAWNS

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Survival (%) of the juvenile and all size class categories were subjected to response surface analysis. Both transformed and untransformed models were fitted to the juvenile data. The transformed model was

$$y^{1.008} = 63.2443 + 0.119244x_1^{1.884} + 6.45172x_2^{0.502} + 0.00288621x_1^{3.768} - 0.402269x_2^{1.004} - 0.140977x_1^{1.884} x_2^{0.502}$$

where y = percent survival
x_1 = initial size
x_2 = stocking density

The transformed survival model offered a marginal improvement over the untransformed model (ANOVA Appendix 2). A contour plot of the model predicting the survival of prawns reared at various stocking densities and mean weights for eight week sorting periods appears in Figure 2.

Although analysis of variance (Appendix 3) indicated the transformed model of survival a better fit for the data for all size classes, visual inspection of the plotted models suggested the untransformed model was more accurate in the immediate vicinity of the experimental design. The untransformed model was

$$y = 107.484 - 7.21437x_1 - 0.17635x_2 + .0119375x_1^2 + 0.0000219177x_2^2 + 0.00476196x_1 x_2$$

where y = percent survival
x_1 = initial size
x_2 = stocking density

A contour plot of the model appears in Figure 3. The analysis of variance table appears in Appendix 4.

3.2 Size

Stocking density had a significant effect on the final mean size of juvenile prawns in each eight week experiment. Although mean weights for individual size categories were comparable at the start of each eight week experiment, the highest final mean weights were found at the lowest stocking densities. Exceptions occurred where survival was minimal. Significant models were obtained for each experiment except weeks 24-32 (Table 2).

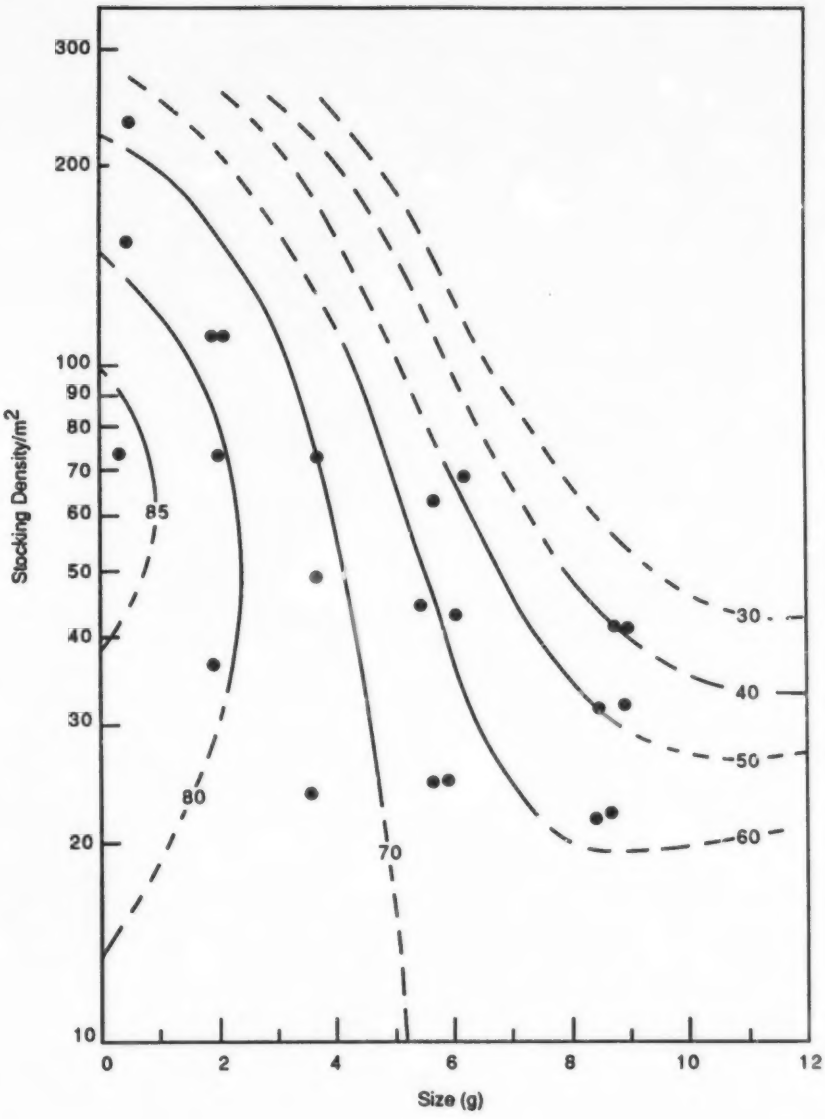

FIGURE 2

CONTOURS OF SURVIVAL (%) OF JUVENILE PRAWNS

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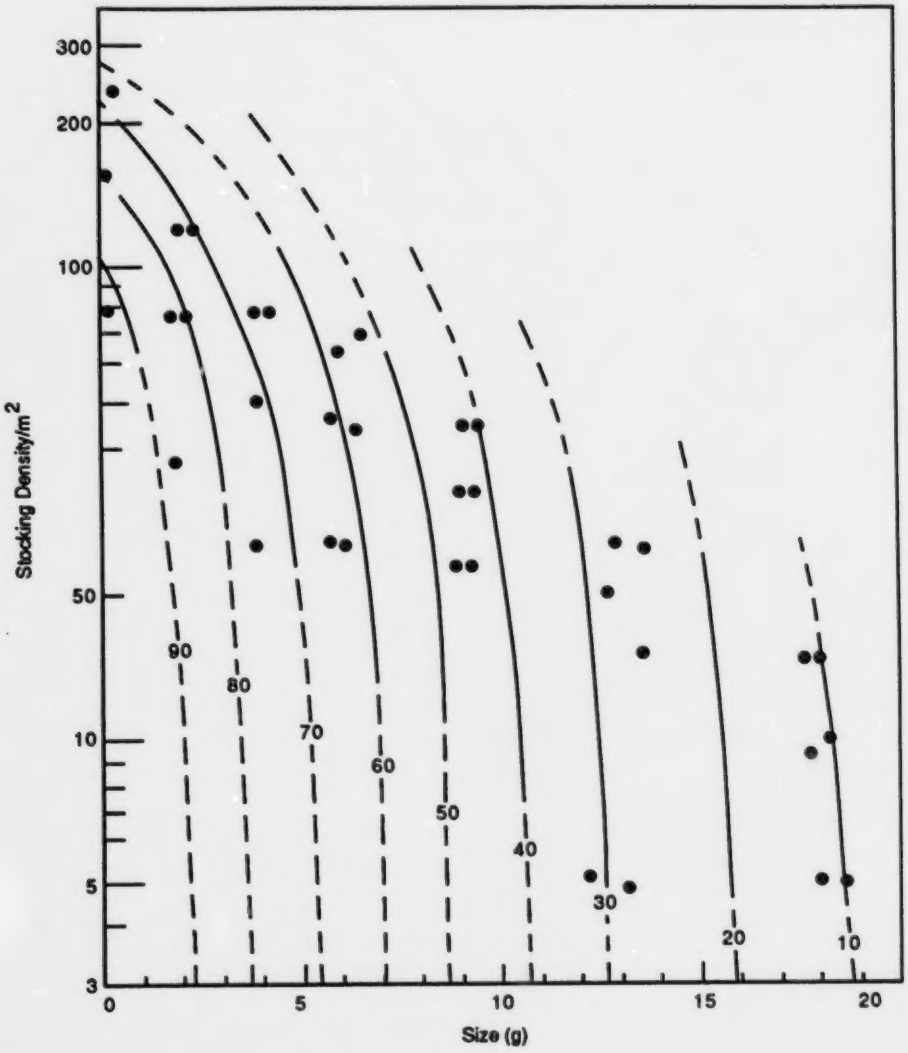

FIGURE 3

CONTOURS OF SURVIVAL (%) OF PRAWNS OF ALL SIZE CLASSES

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TABLE 2

EFFECT OF STOCKING DENSITY AND SIZE SORTING ON THE YIELD OF *M. rosenbergii*

MODELS OF THE CHANGE IN MEAN WEIGHTS OF PRAWNS

EXPERIMENT	NO. OF POINTS	MODEL	MODEL SIGNIFICANCE	R^2
1	9	$y=3.517-0.242\ln_i$	0.0003	0.86
2	12	$y=3.177-0.624\ln m_i-0.270\ln_i$	0.0001	0.92
3	12	$y=2.385-0.450\ln m_i-0.174\ln_i$	0.0008	0.80
4	12	no significant model		

Note: the dependent variable is $y=\ln((m_f - m_i)/m_i +1)$

TABLE 3

EFFECT OF STOCKING DENSITY AND SIZE SORTING ON THE YIELD OF *M. rosenbergii*

MODELS FOR CHANGE IN BIOMASS OF PRAWNS

EXPERIMENT	NO. OF POINTS	MODEL	MODEL SIGNIFICANCE	R^2
1	9	$y=4.577-0.480\ln_i$	0.0002	0.88
2	12	$y=3.469-0.907\ln m_i-0.303\ln_i$	0.0001	0.95
3	12	$y=5.058-1.244\ln m_i-0.531\ln_i$	0.0001	0.88
4	12	no significant model		

Note: the dependent variable is $y=\ln((b_f - b_i)/b_i +1)$

In populations exhibiting heterogenous individual growth, size variation (standard deviation) and skewness of size distribution should be considered in addition to average size. Statgraphics was used to produce a series of descriptive statistics using individual prawn weights from all treatment replicates. Results are summarized in Appendix 5. Although standard deviations and skewness of the size-frequency distributions of the prawns were comparable for individual size categories at the beginning of each experiment, at the end of each experiment it was apparent that stocking density had affected the population structure.

Standard deviations of weights of prawns raised at low densities were larger for Experiment 1 and among the small animals of each subsequent experiment. Deviations peaked at the medium density for the large fraction of prawns for subsequent experiments. However no correlation between the the standard deviations of the initial and final transformed weights was apparent (Figure 4). Thus standard deviation increased only as a function of final mean weight.

Standardized skewness decreased with mean weight. For prawns with mean stocking weights below 10 grams lowest standardized skewness of surviving prawns was obtained at low stocking densities. At stocking weights above 10 grams patterns in standardized skewness were not discernable.

Prawns regarded as small had weights below the overall mean of the stocked prawns and generally exhibited negatively skewed size distributions. Prawns considered large had weights above the overall mean resulting in positively skewed distributions.

However, at the end of each eight week experiment the size-frequency distributions of both the small and large animals were positively skewed. The positive skewness resulted in median weights which were consistently, though not significantly, lower than mean weights.

3.3 Biomass

Final biomass was largely dependent on initial biomass. This relationship changed with increasing size shown by the decreasing slopes of the lines in Figure 5. However, changes in biomass, calculated as the ratio between final and initial biomass, were highest at low stocking densities and lowest at the highest stocking densities in each experiment for any size class (Appendix 1). The change in biomass, standardized by the initial biomass and the natural log of the number stocked per cage, decreased as initial density increased for juvenile prawns (Figure 6). For the 8 to 16 and the 16 to 24 week experiments

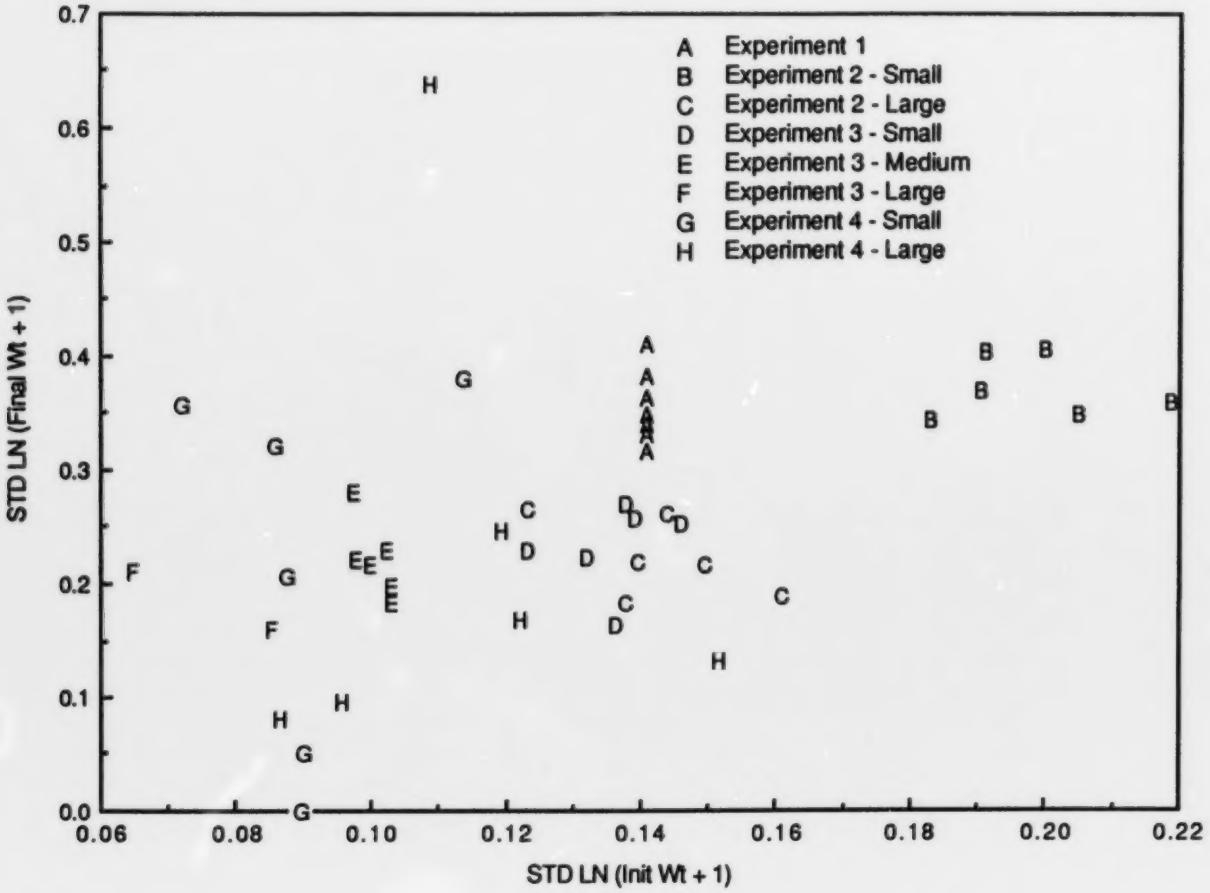

FIGURE 4

STANDARD DEVIATIONS OF FINAL VS INITIAL TRANSFORMED WEIGHTS OF PRAWNS OF ALL SIZE CLASSES

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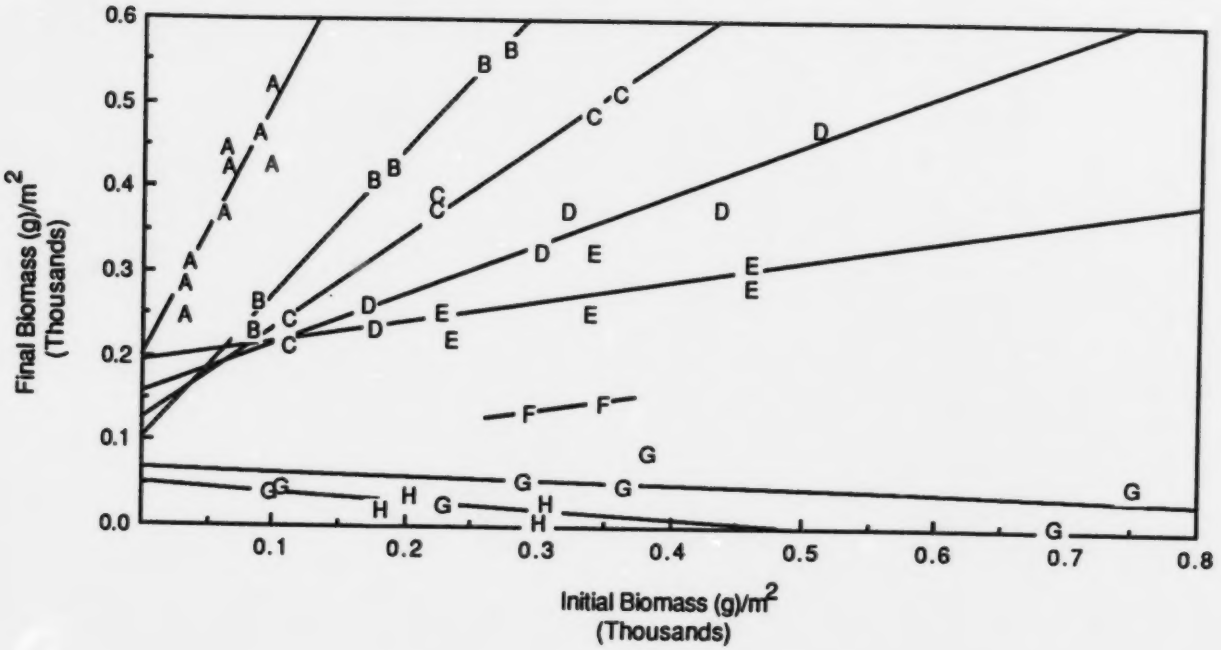

A Experiment 1
B Experiment 2 - Small
C Experiment 2 - Large
D Experiment 3 - Small
E Experiment 3 - Medium
F Experiment 3 - Large
G Experiment 4 - Small
H Experiment 4 - Large

FIGURE 5

CHANGE IN BIOMASS OF PRAWNS OF ALL SIZE CLASSES

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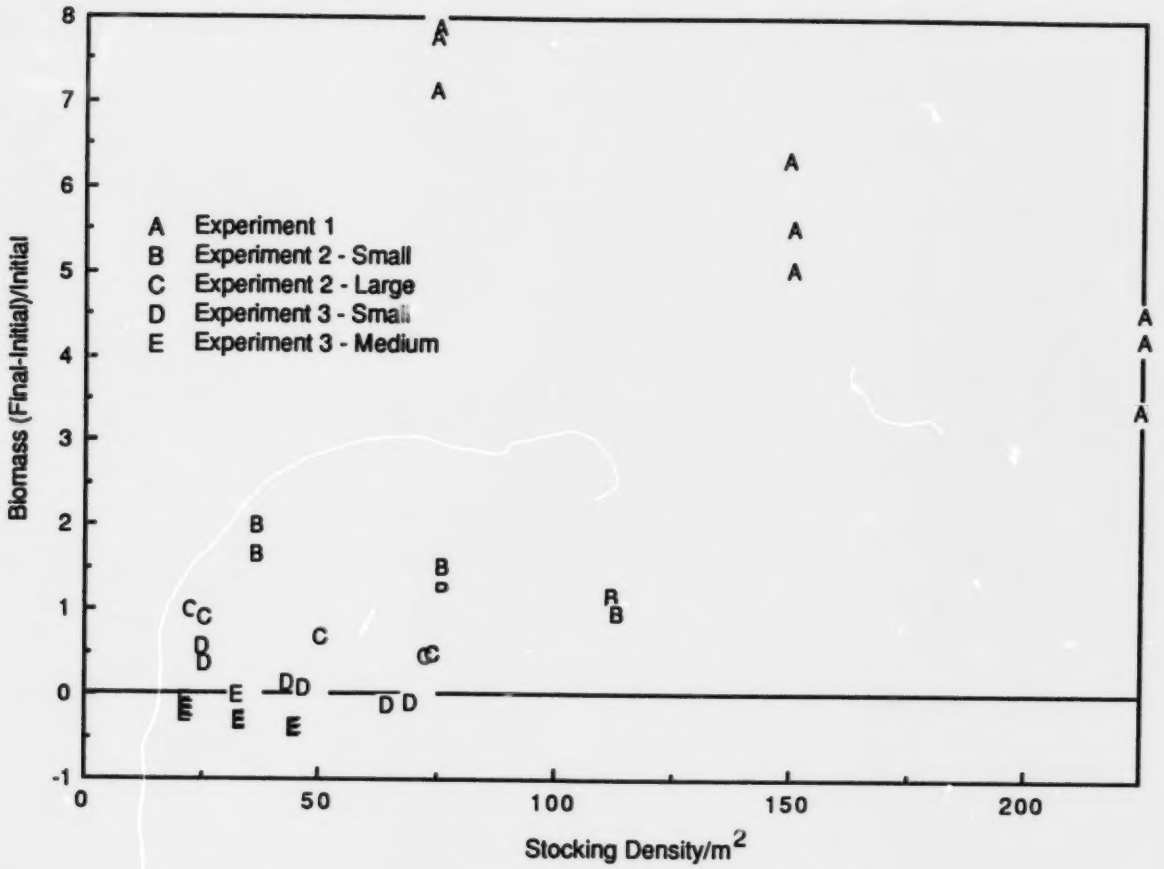

FIGURE 6

CHANGE IN BIOMASS VS DENSITY OF JUVENILE PRAWNS

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change in biomass decreased with stocking weight as well. No significance was detected for the 24 to 32 week experiment (Table 3).

3.4 Optimization Index

Analysis of results showed that stocking density affects survival, mean weight and biomass of prawns. Standard deviations, however, were only related to final mean weight. An optimization index based on these variables was formulated to determine the optimum stocking density to use for any stocking size. The optimization index was calculated as the product of density, survival, biomass and mean size with each variable standardized to derive comparable index values for all size categories and experiments. The index was calculated as follows

$$\text{Index} = SD \times SS \times SB \times SM$$

where SD = standardized density = $N_i/(\max N_i)$

SS = " survival = $(N_f/N_i)/(\max N_f/N_i)$

SB = " biomass = $(B_f/B_i)/(\max B_f/B_i)$

SM = " mean size = $((x_f-x_i)/x_i)/(\max (x_f-x_i))/x_i$

and where i = initial
f = final
N = number of prawns
B = biomass in grams
x = mean weight in grams

The optimization indices for the third size group in the 16-24 week period were distorted due to the small sample size and were therefore not included in subsequent analyses.

Contour plots of the optimization index for juvenile and data for all size classes are shown in Figures 7 and 8 respectively. The lines drawn indicate optimum stocking densities for mean prawn sizes for eight week sorting periods.

The model for juvenile data is

$$y^{0.9995} = 0.1518+0.000499299x_1^{3.000} +.0084167x_2^{0.778} -0.328915E\text{-}07x_1^{6.000} -0.942446E\text{-}04x_2^{1.556} -0.241627E\text{-}04x_1^{3.000} x_2^{0.778}$$

and the model for data from all size classes is

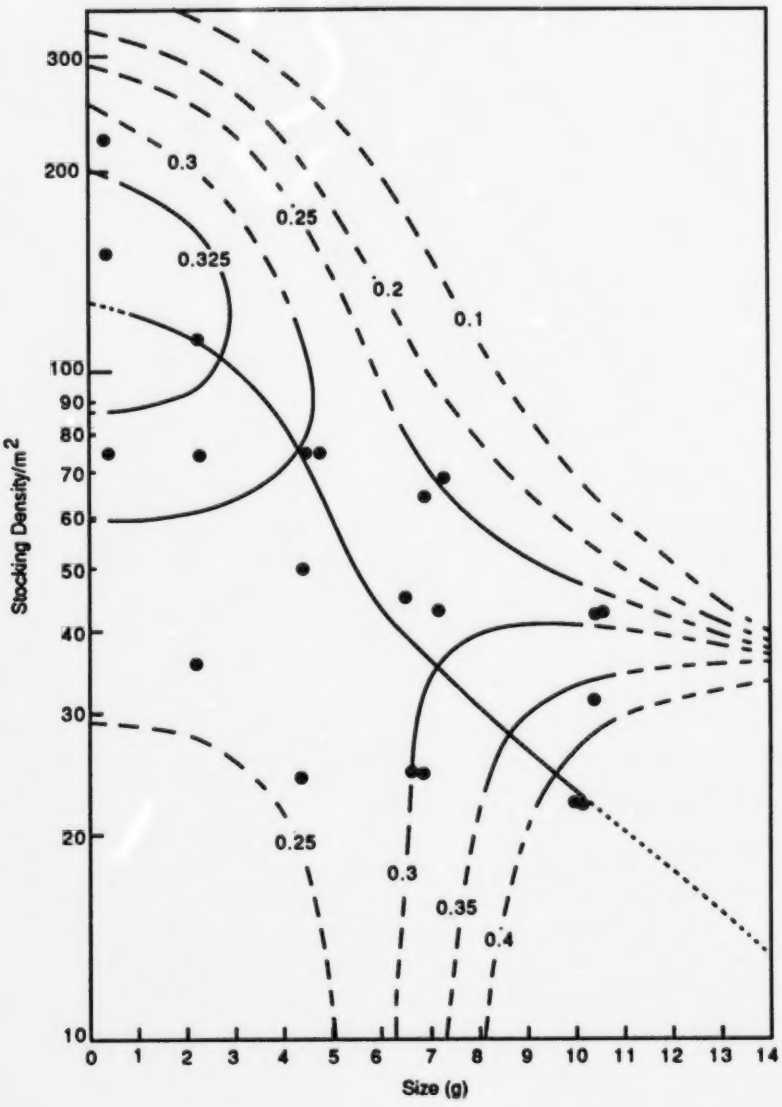

FIGURE 7

JUVENILE PRAWNS
OPTIMIZATION INDEX CONTOURS

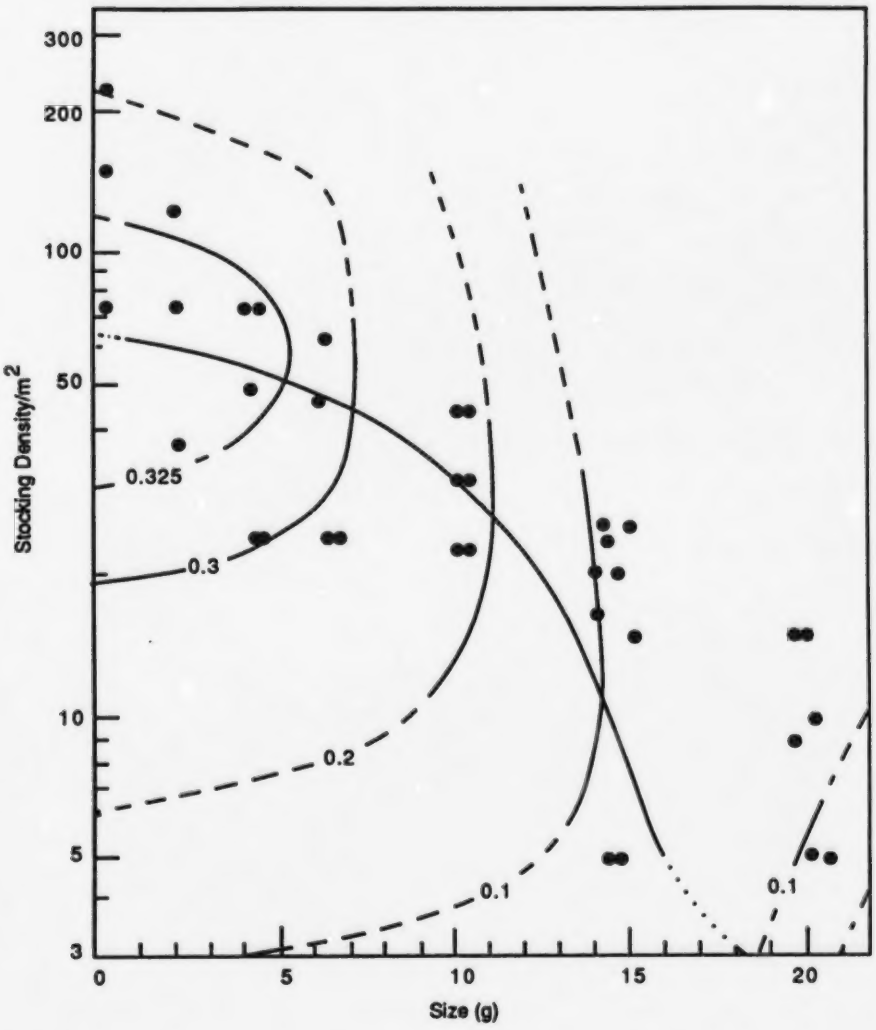

FIGURE 8

PRAWNS OF ALL SIZE CLASSES
OPTIMIZATION INDEX CONTOURS

$$y^{0.7021} = -6.25914 + 0.146125E\text{-}03x_1^{3.333} + 9.89014x_2^{0.074} + 0.750788E\text{-}09x_1^{6.666} - 3.63409x_2^{0.148} - 0.146607E\text{-}03x_1^{3.333} x_2^{0.074}$$

where y = optimization index
x_1 = initial size
x_2 = stocking density

Analysis of variance tables for the juvenile and all size class models appear in Appendices 6 and 7.

4.0 DISCUSSION

4.1 Survival

Sandifer and Smith (1975) studied the effects of population density on the growth and survival of M. rosenbergii reared in recirculated water. Sandifer et al. (1982) monitored growth and survival of M. rosenbergii reared in two semi-intensive trials in a 173 m^2 outdoor tank. Their results were compared with values predicted by the juvenile and all size class models (Table 2). At these stocking sizes and densities, the model for all size classes predicted survival better than the juvenile model. Both models underestimate survival at the higher stocking sizes.

In a recent growout experiment, prawns were stocked in similar cages in a greenhouse environment. Prawns with a mean weight of 0.82 g were stocked at 100/m^2 and reached a mean weight of 4.0 g during the first eight weeks. Seventy-five percent of the prawns remained after eight weeks. The remaining prawns were size sorted and animals above 4.0 g, with a mean weight of 5.54 g, were restocked in cages at 30/m^2 between weeks 8 to 16. The prawns remaining weighed an average of 13 g and were restocked at 25/m^2 in cages at the beginning of the last eight week period. Fifty six percent of the prawns stocked remained in cages at week 16 and 55 % of the prawns stocked remained in cages at week 24. Since some animals escaped from the cages during growout, survival in the cages was underestimated. The juvenile model predicted 83.5 %, 69.5 % and 55.2 % survival for 0-8 weeks, 8-16 weeks and 16-24 weeks respectively. The model for all size classes predicted 84.6 %, 66.7 % and 31 % survival for the same time periods. Both the models overestimated survival during the first two eight week periods. The survival predicted by the model for all size classes underestimated survival for the last eight week period.

Comparison of present results with other studies suggest that the predictive capabilities of the juvenile and all size class models are useful for post-larval and juvenile prawns in intensive and semi-intensive culture. The all size class model offers the best results in the 0.0 - 4.0 g range for stocking densities between 10-300/m^2. Above 70 % survival the juvenile model underestimates survival at low stocking densities. The juvenile model adequately predicts survival in the 4.0 to 14.0 g range for stocking densities in the 5-70/m^2 range. It should be noted that the predictive capabilities of the models above the post-larval to early juvenile sizes (0.0 - 4.0 g) are limited to the cage rearing systems used presently. Other systems may yield different results. Due to poor survival at stocking densities used with animals over 12 g neither model is useful above 14.0 g. Since animals above 12 g were approaching sexual maturity as evidenced by numerous berried females, the poor survival was no doubt related to the socio-physical interaction of the mature prawns.

4.2 Size

Results indicate final size can be enhanced by stocking prawns at low densities. Decreasing stocking density of prawns was found to increase final mean weight. This result is consistant with other studies (Karplus et al., 1986; Smith et al., 1981; Willis and Berrigan, 1977). Standard deviation was unaffected by stocking density and was a function of mean weight. Sandifer and Smith (1975) observed size variance increased with mean length but was unaffected by population density. Karplus et al. (1986) found the coefficient of variation was uniform over the range of densities studied. Standardized skewness which also decreased with final mean weight was least at the lowest stocking densities for prawns below 10 g. Karplus et al. (1986) found skewness of various sexual morphotypes examined varied with increasing stocking rate but the skewness of the whole population was unaffected.

4.3 Biomass

Results which indicated final biomass depended on initial biomass are consistant with other studies (Karplus et al., 1986; Smith et al., 1981; Brody et al., 1980; Willis and Berrigan 1977). The degree of this relationship changed with biomass increasing less rapidly as mean size increased. This is a function of a decreasing capacity for growth as the animals mature (OHRD. 87-91-K).

Biomass, standardized by the initial biomass and the initial number of prawns per cage, was found to increase less rapidly as stocking density increases. Similar results were reported by

researchers working with densities associated with intensive culture (10 - 500 /m2, Sandifer and Smith, 1975; 32 - 83/m2, Sandifer et al, 1982) but not for densities associated with extensive culture (1 - 10/m2, Brody et al., 1980). Thus in intensive prawn culture facilities large final biomass may be obtained only at the expense of individual prawn growth which is inhibited by higher stocking density.

4.4 Optimization Index

The traditional prawn pond management system, which is restricted to tropical and subtropical climates, does not optimize production and relies on limited knowledge of prawn biology and husbandry (Malecha, 1986). To date culture of Macrobrachium rosenbergii in temperate climates has been restricted to seasonal extensive pond culture and isolated semi-intensive culture trials (Smith et al., 1981; Sandifer et al. 1982; Willis and Berrigan, 1977; Brody et al., 1980; Smith et al., 1980). Although McSweeny (1977, in Sandifer et al., 1982) suggested intensive indoor prawn culturing systems would be prohibitively expensive, economic feasibilty of prawn production in temperate climates may be achieved by expanding knowledge and using 'state-of-the-art' techniques to enhance production through large-scale intensive prawn culturing methods.

High total yield per unit area and large market size are the major determinants of the cash value of any harvest. The complex interaction of variables influencing prawn population dynamics and, hence, yield and size make the formulation of intensive culture stategies difficult. The optimization index attempted to define stocking strategies by modelling the most efficient, and therefore cost effective, stocking densities to use for the intensive cage production system presently being investigated by Ontario Hydro. The index incorporates the variables influenced by stocking density and considered most important to profitable production: stocking density (use of space), surviving fraction (harvest potential), biomass (production) and mean size (market price potential). Change in standard deviation (market size/price variability), although an important factor, depended on final mean weight. Since it was not consistantly affected by stocking density, it was excluded.

The results observed in the present study compare favourably with trends reported in previous studies. Thus the index can be used to determine optimum stocking densities for any particular size. The juvenile model is valid for sizes 0.0 - 14.0 g. The model for all size classes, developed for sizes including those over 14.0 g, emphasizes the inability to raise large prawns at high densities using the present culturing system.

Presently the space requirements for the grow-out of large prawns is the limiting factor for a viable intensive prawn aquaculture venture. It has been demonstrated that post-larval and juvenile prawns (< 14.0 g) can be cultured intensively. Future studies should examine strategies and techniques for increasing intensive production of market sized prawns (> 20 g). An economic assessment would aid in determining sizes and yields required for a profitable industry.

5.0 CONCLUSIONS

1. Initial stocking density affects the survival, biomass and mean size of prawns raised in intensive culture. Variance in the size of prawns is a function of final weight and remains uninfluenced by stocking density.

2. Limited control of prawn population dynamics is feasible through the manipulation of stocking density combined with size sorting.

3. Two response surface models were developed using an optimization index to assist the definition of optimum stocking densities for prawns of post larval size to those with mean weights to 14.0 g.

4. Post-larval and juvenile prawns can be raised successfully using the culture system developed to date. However, further research is required to develop intensive culturing techniques for market sized prawns.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. S.A. Bartlett and T.C. Olivares for their contribution to the statistical analysis. Their results appear in OHRDR No. 88-136-K. The authors also wish to thank Dr. J.S. Griffiths and Dr. G.L. Vascotto for critically reviewing the draft report.

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APPENDIX 1

EFFECT OF STOCKING DENSITY AND SIZE SORTING ON YIELD CHARACTERISTICS OF M. ROSENBERGII

DATA SUMMARY

WEEK 0 - INITIAL WEIGHING

CAGE	LOW 1	LOW 2	LOW 3	MED 1	MED 2	MED 3	HIGH 1	HIGH 2	HIGH 3
NO.	150.00	150.00	150.00	300.00	300.00	300.00	450.00	450.00	450.00
MINIMUM	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
MAXIMUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BIOMASS	70.20	65.90	62.00	130.80	120.40	122.40	193.90	186.60	177.80
MEAN	0.47	0.44	0.41	0.44	0.40	0.41	0.43	0.41	0.40
STD	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22

WEEK 8 - WEIGHING

CAGE	LOW 1	LOW 2	LOW 3	MED 1	MED 2	MED 3	HIGH 1	HIGH 2	HIGH 3
NO.	132.00	141.00	119.00	232.00	239.00	207.00	277.00	317.00	309.00
MINIMUM	1.10	1.00	1.30	1.00	0.90	0.80	0.80	0.80	0.80
MAXIMUM	14.70	17.20	10.20	15.10	23.50	14.60	16.90	16.50	14.10
BIOMASS	615.80	582.60	505.30	851.30	880.80	737.80	855.60	1025.70	922.30
MEAN	4.67	4.13	4.25	3.67	3.69	3.56	3.09	3.24	2.98
STD	2.38	2.47	1.71	1.84	2.27	1.82	1.68	1.73	1.59

WEEK 8 - SUMMARY

CAGE	LOW 1	LOW 2	LOW 3	MED 1	MED 2	MED 3	HIGH 1	HIGH 2	HIGH 3
% SURV	88.00	94.00	79.33	77.33	79.67	69.00	61.56	70.44	68.67
ΔBIOMASS	8.77	8.84	8.15	6.51	7.32	6.03	4.41	5.50	5.19
ΔMEAN	8.97	8.40	9.27	7.42	8.18	7.74	6.17	6.80	6.55
ΔSTD	10.80	11.22	7.78	8.36	10.30	8.26	7.63	7.87	7.25
INDEX	0.30	0.30	0.26	0.32	0.41	0.28	0.22	0.34	0.30

WEEK 8 - INITIAL WEIGHING

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LL1	LL2	ML1	ML2	HL1	HL2
NO.	74.00	74.00	150.00	150.00	225.00	224.00	49.00	49.00	100.00	100.00	151.00	150.00
MINIMUM	0.80	1.00	0.80	0.90	1.00	0.80	3.50	3.50	3.50	3.50	2.90	3.40
MAXIMUM	3.40	3.40	3.50	5.20	3.40	3.50	6.50	6.50	6.40	6.20	6.50	6.50
BIOMASS	172.40	174.80	357.70	347.30	545.30	514.10	219.90	216.90	442.20	443.50	712.60	678.70
MEAN	2.33	2.36	2.38	2.32	2.42	2.30	4.49	4.43	4.42	4.44	4.72	4.52
STD	0.62	0.61	0.58	0.67	0.61	0.68	0.77	0.91	0.77	0.69	0.85	0.82

WEEK 16 - WEIGHING

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LL1	LL2	ML1	ML2	HL1	HL2
NO.	56.00	58.00	124.00	132.00	184.00	174.00	36.00	39.00	68.00	71.00	100.00	103.00
MINIMUM	2.10	2.60	1.50	2.00	1.80	2.10	7.00	7.70	6.10	5.30	5.90	3.90
MAXIMUM	15.50	22.20	27.40	18.60	18.50	17.70	19.50	22.10	20.80	31.00	19.70	28.90
BIOMASS	454.30	528.90	847.40	833.90	1111.90	1096.30	428.50	508.40	758.50	768.30	1017.30	970.60
MEAN	8.11	9.12	6.83	6.32	6.04	6.30	11.90	13.04	11.15	10.82	10.17	9.42
STD	3.33	3.73	3.01	2.58	2.73	2.61	2.35	2.88	2.76	3.85	2.61	3.18

WEEK 16 - SUMMARY

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LL1	LL2	ML1	ML2	HL1	HL2
% SURV	75.68	78.38	82.67	88.00	81.78	77.68	73.47	79.59	68.00	71.00	66.23	68.67
ΔBIOMASS	2.64	3.03	2.37	2.40	2.04	2.13	1.95	2.34	1.72	1.73	1.43	1.43
ΔMEAN	2.48	2.86	1.87	1.73	1.49	1.75	1.65	1.94	1.52	1.44	1.16	1.08
ΔSTD	5.33	6.15	5.16	3.87	4.46	3.87	3.05	3.18	3.59	5.60	3.07	3.86
INDEX	0.21	0.29	0.32	0.32	0.33	0.38	0.21	0.32	0.32	0.32	0.30	0.29

APPENDIX 1

EFFECT OF STOCKING DENSITY AND SIZE SORTING ON YIELD CHARACTERISTICS OF M. ROSENBERGII

DATA SUMMARY - CONTINUED

WEEK 16 - INITIAL WEIGHING

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LM1	LM2	MM1	MM2	HM1	HM2	LL1	LL2
NO.	50.00	50.00	92.00	88.00	139.00	129.00	45.00	45.00	65.00	65.00	87.00	87.00	40.00	48.00
MINIMUM	5.00	5.10	5.00	5.00	5.20	5.00	8.70	8.70	8.70	8.80	8.70	8.60	12.90	13.00
MAXIMUM	8.60	8.40	8.60	8.60	8.90	8.60	12.20	12.90	12.70	12.50	12.90	12.90	17.50	16.70
BIOMASS	347.70	334.20	601.90	635.20	1014.20	862.90	464.70	453.40	684.10	681.20	925.30	912.20	588.80	691.90
MEAN	6.95	6.68	6.54	7.22	7.30	6.69	10.33	10.08	10.52	10.48	10.64	10.49	14.72	14.41
STD	1.04	0.99	1.10	1.08	0.98	1.06	1.09	1.12	1.17	1.11	1.19	1.18	1.34	1.01

WEEK 24 - WEIGHING

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LM1	LM2	MM1	MM2	HM1	HM2	LL1	LL2
NO.	33.00	34.00	49.00	58.00	75.00	57.00	23.00	27.00	38.00	27.00	35.00	31.00	13.00	14.00
MINIMUM	9.50	8.50	6.90	6.90	5.60	7.20	14.20	11.50	11.50	10.90	11.40	11.20	17.40	13.30
MAXIMUM	21.70	24.90	26.50	40.70	21.00	29.50	38.30	27.70	26.40	45.60	26.30	31.20	32.80	34.50
BIOMASS	474.70	528.70	656.20	750.60	937.50	746.20	452.10	511.20	657.60	509.50	617.30	570.90	279.40	290.80
MEAN	14.38	15.55	13.39	12.94	12.50	13.09	19.66	18.93	17.31	18.87	17.64	18.42	21.49	20.77
STD	2.54	3.57	3.89	4.82	3.09	3.92	5.40	4.27	3.58	6.83	3.55	4.58	3.80	4.84

WEEK 24 - SUMMARY

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LM1	LM2	MM1	MM2	HM1	HM2	LL1	LL2
% SURV	66.00	68.00	53.26	65.91	53.96	44.19	51.11	60.00	58.46	41.54	40.23	35.63	32.50	29.17
ΔBIOMASS	1.37	1.58	1.09	1.18	0.92	0.86	0.97	1.13	0.96	0.75	0.67	0.63	0.47	0.42
ΔMEAN	1.07	1.33	1.05	0.79	0.71	0.96	0.90	0.88	0.64	0.80	0.66	0.76	0.46	0.44
ΔSTD	2.44	3.60	3.54	4.48	3.15	3.70	4.94	3.80	3.06	6.14	3.00	3.87	2.84	4.80
INDEX	0.24	0.36	0.28	0.27	0.25	0.24	0.38	0.50	0.44	0.30	0.29	0.28	0.83	0.76

WEEK 24 - INITIAL WEIGHING

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LL1	LL2	ML1	ML2	HL1	HL2
NO.	10.00	10.00	40.00	30.00	50.00	50.00	10.00	10.00	18.00	20.00	30.00	30.00
MINIMUM	12.10	12.50	12.30	12.40	13.00	12.40	17.90	17.60	17.30	17.60	17.40	17.70
MAXIMUM	15.70	17.80	16.90	17.50	17.10	17.50	27.40	24.60	24.10	25.40	23.30	25.90
BIOMASS	138.80	149.60	572.30	459.60	724.10	762.70	209.30	202.50	360.40	409.20	600.60	606.70
MEAN	13.88	14.96	14.31	15.32	14.48	15.25	20.93	20.25	20.02	20.46	20.02	20.22
STD	1.27	1.71	1.32	1.41	1.13	1.35	3.31	2.55	1.98	2.31	1.80	2.58

WEEK 30 - WEIGHING

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LL1	LL2	ML1	ML2	HL1	HL2
NO.	0.00	4.00	4.00	2.00	3.00	7.00	3.00	2.00	1.00	2.00	1.00	2.00
MINIMUM	0.00	18.40	18.89	31.79	21.43	17.10	24.68	34.43	35.97	19.04	20.95	22.55
MAXIMUM	0.00	45.00	29.42	34.40	43.70	43.20	32.27	44.20	35.97	48.45	20.95	32.52
BIOMASS	0.00	109.10	106.27	66.19	90.75	191.73	84.66	78.63	35.97	67.49	20.95	55.07
MEAN	0.00	27.28	26.57	33.10	30.25	27.39	28.22	39.32	35.97	33.75	20.95	27.54
STD	0.00	10.52	4.44	1.30	9.66	8.75	3.12	4.88	0.00	14.70	0.00	4.98

WEEK 30 - SUMMARY

CAGE	LS1	LS2	MS1	MS2	HS1	HS2	LL1	LL2	ML1	ML2	HL1	HL2
% SURV	0.00	40.00	10.00	6.67	6.00	14.00	30.00	20.00	5.56	10.00	3.33	6.67
ΔBIOMASS	0.00	0.73	0.19	0.14	0.13	0.25	0.40	0.39	0.10	0.16	0.03	0.09
ΔMEAN	-1.00	0.82	0.86	1.16	1.09	0.80	0.35	0.94	0.80	0.65	0.05	0.36
ΔSTD	NA	6.14	3.37	0.93	8.58	6.46	0.94	1.92	0.00	6.37	0.00	1.93
INDEX	0.00	0.14	0.04	0.02	0.02	0.08	0.12	0.21	0.02	0.06	0.00	0.02

LEGEND X X D ->REPLICATE
| |----->SIZE (S = SMALL, M = MEDIUM, L = LARGE)
|------->DENSITY (L = LOW, M = MEDIUM, H = HIGH)

APPENDIX 2

SURVIVAL MODEL - JUVENILES

ANALYSIS OF VARIANCE TABLE - TRANSFORMED DATA

SOURCE	SS	D.F.	MSS	APPROX. F	MLR
REGRESSION	5735.2461	5	1147.05	29.72	0.727926E-14
LINEAR	3559.9639	2	1779.98	46.12	0.495453E-11
X1 LINEAR	2592.4390	1	2592.44	67.17	0.272732E-09
X2 LINEAR	1057.2589	1	1057.26	27.39	0.349427E-05
QUADRATIC	421.4425	2	210.72	5.46	0.205480E-02
X1 QUAD.	60.1130	1	60.11	1.56	0.354331E+00
X2 QUAD.	208.9564	1	208.96	5.41	0.348564E-01
X1 * X2	363.1035	1	363.10	9.41	0.426461E-01
TRANSFORM	243.9165	3	81.31	0.00	0.211315E-01
RESIDUAL	926.2510	24	38.59		
TOTAL	6661.4971	32			

RELATIVE LIKELIHOOD OF NO TRANSFORMATION VS. ML ESTIMATES = 0.21132E-01

APPENDIX 3

SURVIVAL MODEL - ALL SIZE CLASSES

TRANSFORMED

ANALYSIS OF VARIANCE TABLE - TRANSFORMED DATA

SOURCE	SS	D.F.	MSS	APPROX. F	MLR
REGRESSIONS	34175.1289	5	6835.03	80.38	0.101372E-24
LINEAR	6049.9756	2	3024.99	35.57	0.170386E-10
X1 LINEAR	5624.6753	1	5624.58	66.15	0.513054E-10
X2 LINEAR	1067.5804	1	1067.58	12.56	0.122027E-02
QUADRATIC	2871.6318	2	1435.82	16.89	0.323669E-06
X1 QUAD.	287.3900	1	287.39	3.38	0.135018E+00
X2 QUAD.	528.6793	1	528.68	6.22	0.284102E-01
X1 * X2	413.0980	1	413.10	4.86	0.591744E-01
TRANSFORM	1279.9277	3	426.64	0.00	0.392983E-03
RESIDUAL	3231.2266	38	85.03		
TOTAL	37406.3555	46			

RELATIVE LIKELIHOOD OF NO TRANSFORMATION VS. ML ESTIMATES = 0.39298E-03

APPENDIX 4

SURVIVAL MODEL - ALL SIZE CLASSES

UNTRANSFORMED

ANALYSIS OF VARIANCE TABLE - UN-TRANSFORMED DATA

SOURCE	SS	D.F.	MSS	APPROX. F	MLR
REGRESSIONS	31374.2207	5	6274.84	57.03	0.684225E-21
LINEAR	20419.6094	2	10209.8	92.79	0.356841E-17
X1 LINEAR	2320.0542	1	2320.05	21.09	0.582195E-04
X2 LINEAR	65.9636	1	65.96	0.6	0.710962E+00
QUADRATIC	371.7765	2	185.89	1.69	0.155513E+00
X1 QUAD.	223.3837	1	223.38	2.03	0.321171E+00
X2 QUAD.	0.0790	1	0.08	0	0.999588E+00
X1 * X2	3.5792	1	3.58	0.03	0.981536E+00
RESIDUAL	4511.1543	41	110.03		
TOTAL	35885.3750	46			

APPENDIX 5
SUMMARY STATISTICS
EXPERIMENT 1

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY	SAMPLE
SAMPLE SIZE	450	900	1350	235
AVERAGE				0.455745
MEDIAN				0.4
MODE				0.3
GEOMETRIC MEAN				0.406212
VARIANCE				0.0493151
STANDARD DEVIATION				0.22207
STANDARD ERROR				0.0144863
MINIMUM				0.2
MAXIMUM				1
RANGE				0.8
LOWER QUARTILE				0.3
UPPER QUARTILE				0.6
INTERQUARTILE RANGE				0.3
SKEWNESS				0.808578
STANDARDIZED SKEWNESS				5.06035
KURTOSIS				-0.290631
STANDARDIZED KURTOSIS				-0.909431

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	392	678	903
AVERAGE	4.34617	3.64292	3.10476
MEDIAN	3.9	3.3	2.8
MODE	2.5	2.1	2.2
GEOMETRIC MEAN	3.87389	3.23706	2.77225
VARIANCE	5.04843	3.98647	2.80112
STANDARD DEVIATION	2.24687	1.99661	1.67365
STANDARD ERROR	0.113484	0.0766795	0.0556957
MINIMUM	1	0.8	0.8
MAXIMUM	17.2	23.5	16.9
RANGE	16.2	22.7	16.1
LOWER QUARTILE	2.7	2.3	2
UPPER QUARTILE	5.3	4.4	3.7
INTERQUARTILE RANGE	2.6	2.1	1.7
SKEWNESS	1.86529	2.85002	2.72948
STANDARDIZED SKEWNESS	15.077	30.2961	33.4849
KURTOSIS	6.2572	17.9647	14.4274
STANDARDIZED KURTOSIS	25.2882	95.4839	88.4968

EXPERIMENT 2

SMALL PRAWNS

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	148	300	449
AVERAGE	2.34595	2.35	2.35947
MEDIAN	2.4	2.4	2.4
MODE	2.5	2.5	2.2
GEOMETRIC MEAN	2.25485	2.25965	2.25779
VARIANCE	0.381956	0.395084	0.420943
STANDARD DEVIATION	0.618026	0.628557	0.648801
STANDARD ERROR	0.0508014	0.0362897	0.0306188
MINIMUM	0.8	0.8	0.8
MAXIMUM	3.4	5.2	3.5
RANGE	2.6	4.4	2.7
LOWER QUARTILE	1.9	1.9	1.9
UPPER QUARTILE	2.9	2.8	2.9
INTERQUARTILE RANGE	1	0.9	1
SKEWNESS	-0.233456	0.11759	-0.261378
STANDARDIZED SKEWNESS	-1.15947	0.831485	-2.26109
KURTOSIS	-0.708494	0.432123	-0.751213
STANDARDIZED KURTOSIS	-1.75939	1.52778	-3.24923

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	114	256	358
AVERAGE	8.62456	6.56758	6.16816
MEDIAN	8.7	6.4	5.9
MODE	8.3	6.4	5.4
GEOMETRIC MEAN	7.81158	6.04711	5.61843
VARIANCE	12.892	7.91357	7.18817
STANDARD DEVIATION	3.59054	2.81311	2.68108
STANDARD ERROR	0.336285	0.175819	0.141699
MINIMUM	2.1	1.5	1.8
MAXIMUM	22.2	27.4	18.5
RANGE	20.1	25.9	16.7
LOWER QUARTILE	6	4.65	4.1
UPPER QUARTILE	10.9	8	7.8
INTERQUARTILE RANGE	4.9	3.35	3.7
SKEWNESS	0.452541	2.14459	1.03736
STANDARDIZED SKEWNESS	1.97258	14.0084	8.01297
KURTOSIS	0.714871	12.1161	2.05384
STANDARDIZED KURTOSIS	1.55802	39.571	7.93236

EXPERIMENT 2

LARGE PRAWNS

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	98	200	301
AVERAGE	4.45714	4.4285	4.62226
MEDIAN	4.1	4.3	4.4
MODE	3.6	3.5	4
GEOMETRIC MEAN	4.38242	4.37159	4.5483
VARIANCE	0.715876	0.534108	0.713336
STANDARD DEVIATION	0.846095	0.730827	0.844592
STANDARD ERROR	0.0854685	0.0516773	0.0486815
MINIMUM	3.5	3.5	2.9
MAXIMUM	6.5	6.8	6.5
RANGE	3	3.3	3.6
LOWER QUARTILE	3.7	3.8	3.9
UPPER QUARTILE	5.1	4.9	5.3
INTERQUARTILE RANGE	1.4	1.1	1.4
SKEWNESS	0.687039	0.71212	0.527069
STANDARDIZED SKEWNESS	2.77664	4.11143	3.73315
KURTOSIS	-0.763013	-0.133851	-0.7576
STANDARDIZED KURTOSIS	-1.54184	-0.386395	-2.68298

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	75	139	203
AVERAGE	12.492	10.9842	9.79261
MEDIAN	2.1	10.6	9.2
MODE	13.7	11.1	8.6
GEOMETRIC MEAN	12.2195	10.5734	9.43196
VARIANCE	7.38264	11.4071	8.67554
STANDARD DEVIATION	2.7171	3.37745	2.94543
STANDARD ERROR	0.313744	0.286471	0.206728
MINIMUM	7	5.3	3.9
MAXIMUM	22.1	31	28.9
RANGE	15.1	25.7	25
LOWER QUARTILE	10.7	8.8	7.9
UPPER QUARTILE	13.7	12.3	11
INTERQUARTILE RANGE	3	3.5	3.1
SKEWNESS	1.01466	2.36303	2.11718
STANDARDIZED SKEWNESS	3.548737	11.3737	12.3149
KURTOSIS	2.0824	10.2184	8.97574
STANDARDIZED KURTOSIS	3.6812	24.5915	26.1043

EXPERIMENT 3

SMALL PRAWNS

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	100	180	268
AVERAGE	6.819	6.87278	7.0041
MEDIAN	6.9	6.9	7.2
MODE	6.4	8.6	8.3
GEOMETRIC MEAN	6.73989	6.77632	6.92041
VARIANCE	1.06196	1.3059	1.13702
STANDARD DEVIATION	1.03051	1.14276	1.06631
STANDARD ERROR	0.103051	0.0851764	0.0651355
MINIMUM	5	5	5
MAXIMUM	8.6	8.6	8.9
RANGE	3.6	3.6	3.9
LOWER QUARTILE	5.9	5.8	6.1
UPPER QUARTILE	7.65	7.9	7.9
INTERQUARTILE RANGE	1.75	2.1	1.8
SKEWNESS	-0.102381	-0.0395414	-0.177445
STANDARDIZED SKEWNESS	-0.417969	-0.216577	-1.18592
KURTOSIS	-1.15199	-1.35112	-1.13741
STANDARDIZED KURTOSIS	-2.35149	-3.70018	-3.80082

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	67	107	132
AVERAGE	14.9761	13.1477	12.7553
MEDIAN	14.9	12.4	12.3
MODE	16.1	10.7	10.5
GEOMETRIC MEAN	14.6494	12.595	12.3199
VARIANCE	10.1406	19.7416	12.2303
STANDARD DEVIATION	3.18444	4.44315	3.49718
STANDARD ERROR	0.389041	0.429535	0.304391
MINIMUM	8.5	6.9	5.6
MAXIMUM	24.9	40.7	29.5
RANGE	16.4	33.8	23.9
LOWER QUARTILE	12.6	10.7	10.5
UPPER QUARTILE	16.3	14.7	14.35
INTERQUARTILE RANGE	3.7	4	3.85
SKEWNESS	0.601763	2.84867	1.20031
STANDARDIZED SKEWNESS	2.01088	12.0298	5.62997
KURTOSIS	0.946461	13.9246	3.26533
STANDARDIZED KURTOSIS	1.58137	29.4014	7.65789

EXPERIMENT 3

MEDIUM PRAWNS

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	90	130	174
AVERAGE	10.2011	10.5023	10.5603
MEDIAN	10	10.4	10.5
MODE	9	8.8	10.1
GEOMETRIC MEAN	10.1415	10.4408	10.4943
VARIANCE	1.25809	1.31635	1.41767
STANDARD DEVIATION	1.12165	1.14732	1.19066
STANDARD ERROR	0.118232	0.100627	0.0902636
MINIMUM	8.7	8.7	8.6
MAXIMUM	12.9	12.7	12.9
RANGE	4.2	4	4.3
LOWER QUARTILE	9.1	9.5	9.5
UPPER QUARTILE	11.1	11.3	11.4
INTERQUARTILE RANGE	2	1.8	1.9
SKEWNESS	0.429527	0.257716	0.262319
STANDARDIZED SKEWNESS	1.66355	1.1996	1.41263
KURTOSIS	-0.895304	-1.04399	-0.948452
STANDARDIZED KURTOSIS	-1.73375	-2.42976	-2.55378

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	50	65	66
AVERAGE	19.266	17.9554	18.003
MEDIAN	18.5	16.7	17.65
MODE	16.4	17.3	15.3
GEOMETRIC MEAN	18.7352	17.3697	17.58
VARIANCE	23.8672	27.9016	16.9732
STANDARD DEVIATION	4.88541	5.28219	4.11986
STANDARD ERROR	0.690901	0.655176	0.507119
MINIMUM	11.5	10.9	11.2
MAXIMUM	38.3	45.6	31.2
RANGE	26.8	34.7	20
LOWER QUARTILE	16	14.9	15.4
UPPER QUARTILE	21.7	19.9	19.1
INTERQUARTILE RANGE	5.7	5	3.7
SKEWNESS	1.45562	2.61359	1.10479
STANDARDIZED SKEWNESS	4.20203	8.60237	3.66419
KURTOSIS	3.5143	11.1916	1.51224
STANDARDIZED KURTOSIS	5.07246	18.418	2.50777

EXPERIMENT 3

LARGE PRAWNS

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY
SAMPLE SIZE	40	48
AVERAGE	14.72	14.4146
MEDIAN	14.55	14
MODE	13.4	14
GEOMETRIC MEAN	14.6609	14.3803
VARIANCE	1.83549	1.03659
STANDARD DEVIATION	1.3548	1.01813
STANDARD ERROR	0.214213	0.146955
MINIMUM	12.9	13
MAXIMUM	17.5	16.7
RANGE	4.6	3.7
LOWER QUARTILE	13.5	13.6
UPPER QUARTILE	15.6	15.35
INTERQUARTILE RANGE	2.1	1.75
SKEWNESS	0.576434	0.647617
STANDARDIZED SKEWNESS	1.48835	1.83174
KURTOSIS	-0.706435	-0.667375
STANDARDIZED KURTOSIS	-0.912003	-0.943811

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY
SAMPLE SIZE	13	14
AVERAGE	21.4923	20.7714
MEDIAN	20.6	20.5
MODE	20.6	19.5
GEOMETRIC MEAN	21.2049	20.2755
VARIANCE	15.6724	25.2084
STANDARD DEVIATION	3.95884	5.02079
STANDARD ERROR	1.09799	1.34186
MINIMUM	17.4	13.3
MAXIMUM	32.8	34.5
RANGE	15.4	21.2
LOWER QUARTILE	19.3	18.1
UPPER QUARTILE	22.5	21.4
INTERQUARTILE RANGE	3.2	3.3
SKEWNESS	2.03377	1.548
STANDARDIZED SKEWNESS	2.99363	2.36462
KURTOSIS	5.6437	3.95481
STANDARDIZED KURTOSIS	4.15365	3.02053

EXPERIMENT 4

SMALL PRAWNS

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	20	70	100
AVERAGE	14.42	14.7414	14.868
MEDIAN	14.15	14.95	14.75
MODE	15.7	15.1	13
GEOMETRIC MEAN	14.333	14.6702	14.8113
VARIANCE	2.70168	2.11985	1.71634
STANDARD DEVIATION	1.64368	1.45597	1.31009
STANDARD ERROR	0.367538	0.174022	0.131009
MINIMUM	12.1	12.3	12.4
MAXIMUM	17.8	17.5	17.5
RANGE	5.7	5.2	5.1
LOWER QUARTILE	13.05	13.5	13.8
UPPER QUARTILE	15.6	15.8	15.9
INTERQUARTILE RANGE	2.55	2.3	2.1
SKEWNESS	0.472528	0.0395049	0.233528
STANDARDIZED SKEWNESS	0.862714	0.134935	0.953373
KURTOSIS	-0.487136	-0.943768	-0.946076
STANDARDIZED KURTOSIS	-0.444692	-1.61179	-1.93117

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	4	6	10
AVERAGE	27.275	23.7433	28.248
MEDIAN	22.85	29.205	25.31
MODE	18.4	28.97	22.11
GEOMETRIC MEAN	25.5744	28.2696	26.8756
VARIANCE	147.685	27.7877	92.5914
STANDARD DEVIATION	12.1526	5.2714	9.62244
STANDARD ERROR	6.07628	2.15204	3.04288
MINIMUM	18.4	18.89	17.1
MAXIMUM	45	34.4	43.7
RANGE	26.6	15.51	26.6
LOWER QUARTILE	19.455	28.97	21.43
UPPER QUARTILE	35.095	31.79	35.84
INTERQUARTILE RANGE	15.64	2.82	14.41
SKEWNESS	1.69051	-1.52995	0.731037
STANDARDIZED SKEWNESS	1.3803	-1.52995	0.943765
KURTOSIS	2.85643	3.30178	-0.854735
STANDARDIZED KURTOSIS	1.16613	1.65089	-0.551729

EXPERIMENT 4

LARGE PRAWNS

INITIAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	20	38	60
AVERAGE	20.59	20.2526	20.1217
MEDIAN	19.05	20	19.45
MODE	18.7	18.3	17.7
GEOMETRIC MEAN	20.39	20.1393	20.0043
VARIANCE	9.30621	4.84256	5.0502
STANDARD DEVIATION	3.05061	2.20058	2.24727
STANDARD ERROR	0.682137	0.356982	0.290121
MINIMUM	17.6	17.3	17.4
MAXIMUM	27.4	25.4	25.9
RANGE	9.8	8.1	8.5
LOWER QUARTILE	18.2	18.3	18.15
UPPER QUARTILE	23.65	21.8	21.6
INTERQUARTILE RANGE	5.45	3.5	3.45
SKEWNESS	0.948602	0.511537	0.847639
STANDARDIZED SKEWNESS	1.7319	1.28734	2.68047
KURTOSIS	-0.487917	-0.737434	-0.178234
STANDARDIZED KURTOSIS	-0.445405	-0.927917	-0.281813

FINAL WEIGHING

VARIABLE:	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY
SAMPLE SIZE	5	3	3
AVERAGE	32.658	34.4867	25.34
MEDIAN	32.27	35.97	22.55
MODE	27.71	19.04	20.95
GEOMETRIC MEAN	32.0057	32.1342	24.8596
VARIANCE	56.1599	217.887	39.3043
STANDARD DEVIATION	7.49399	14.761	6.26931
STANDARD ERROR	3.35141	8.52227	3.61959
MINIMUM	24.68	19.04	20.95
MAXIMUM	44.2	48.45	32.52
RANGE	19.52	29.41	11.57
LOWER QUARTILE	27.71	19.04	20.95
UPPER QUARTILE	34.43	48.45	32.52
INTERQUARTILE RANGE	6.72	29.41	11.57
SKEWNESS	0.905065	-0.447639	1.606
STANDARDIZED SKEWNESS	0.826208	-0.316528	1.13561
KURTOSIS	0.880738	0	0
STANDARDIZED KURTOSIS	0.402	0	0

APPENDIX 6

OPTIMIZATION INDEX MODEL FOR JUVENILES

ANALYSIS OF VARIANCE TABLE - TRANSFORMED DATA

SOURCE	SS	D.F.	MSS	APPROX. F	MLR
REGRESSIONS	0.0646	5	0.01	4.97	0.811435E-05
LINEAR	0.0334	2	0.02	6.43	0.845138E-03
X1 LINEAR	0.0248	1	0.02	9.52	0.403428E-02
X2 LINEAR	0.0328	1	0.03	12.59	0.951478E-03
QUADRATIC	0.0151	2	0.01	2.9	0.279786E-01
X1 QUAD.	0.0003	1	0.00	0.1	0.931062E+00
X2 QUAD.	0.0148	1	0.01	5.68	0.300100E-01
X1 * X2	0.0455	1	0.05	17.49	0.119635E-03
TRANSFORM	0.0171	3	0.01	0.00	0.185701E-01
RESIDUAL	0.0625	24	0.00		
TOTAL	0.1271	32			

RELATIVE LIKELIHOOD OF NO TRANSFORMATION VS. ML ESTIMATES = 0.18570E-01

APPENDIX 7

OPTIMIZATION INDEX MODEL FOR ALL SIZE CLASSES

ANALYSIS OF VARIANCE TABLE - TRANSFORMED DATA

SOURCE	SS	D.F.	MSS	APPROX. F	MLR
REGRESSION	0.5151	5	0.10	16.77	0.177095E-11
LINEAR	0.1012	2	0.05	8.24	0.207476E-03
X1 LINEAR	0.0966	1	0.10	15.73	0.286717E-03
X2 LINEAR	0.0074	1	0.01	1.21	0.475180E+00
QUADRATIC	0.0651	2	0.03	5.30	0.301413E-02
X1 QUAD.	0.0092	1	0.01	1.49	0.400996E+00
X2 QUAD.	0.0151	1	0.02	2.46	0.226046E+00
X1 * X2	0.0241	1	0.02	3.92	0.974970E-01
TRANSFORM	0.1060	3	0.04	0.00	0.149641E-03
RESIDUAL	0.2212	36	0.01		
TOTAL	0.7363	44			

RELATIVE LIKELIHOOD OF NO TRANSFORMATION VS. ML ESTIMATES = 0.14964E-03